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Innovative High-Performance Rocket Engines Based On Hybrid Composites-Metal Design

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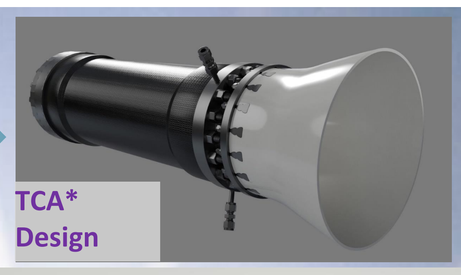
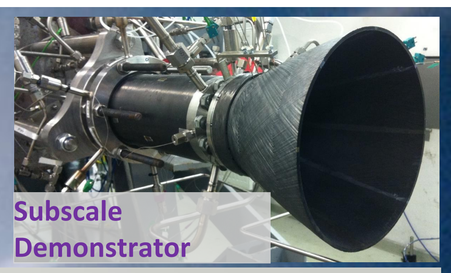
Transpiration Cooled Ceramic Rocket Thrust Chamber

AT A GLANCE

* **TCA –** Thrust Chamber Assembly
CMC – Ceramic Matrix Composites
CFRP – Carbon Fibre Reinforced Plastics
O-CMC – Oxidic CMC

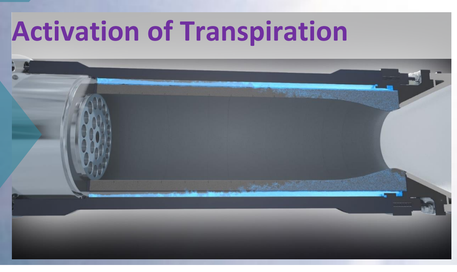
Rocket TCA

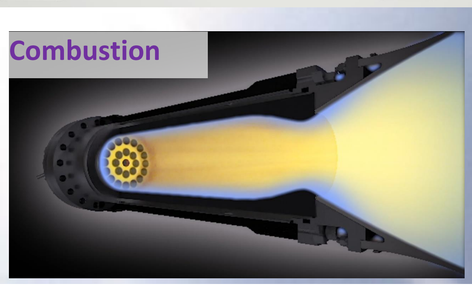




Structural Principle

Function



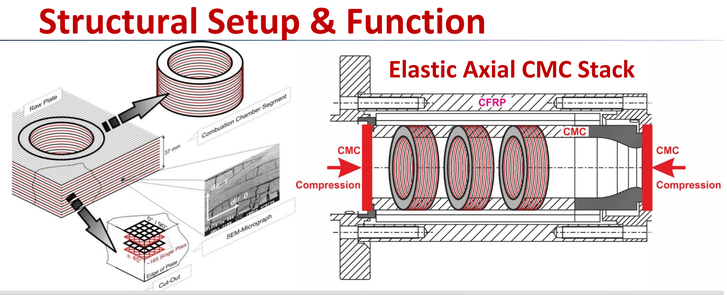


Structural System of the Thrust Chamber Setup

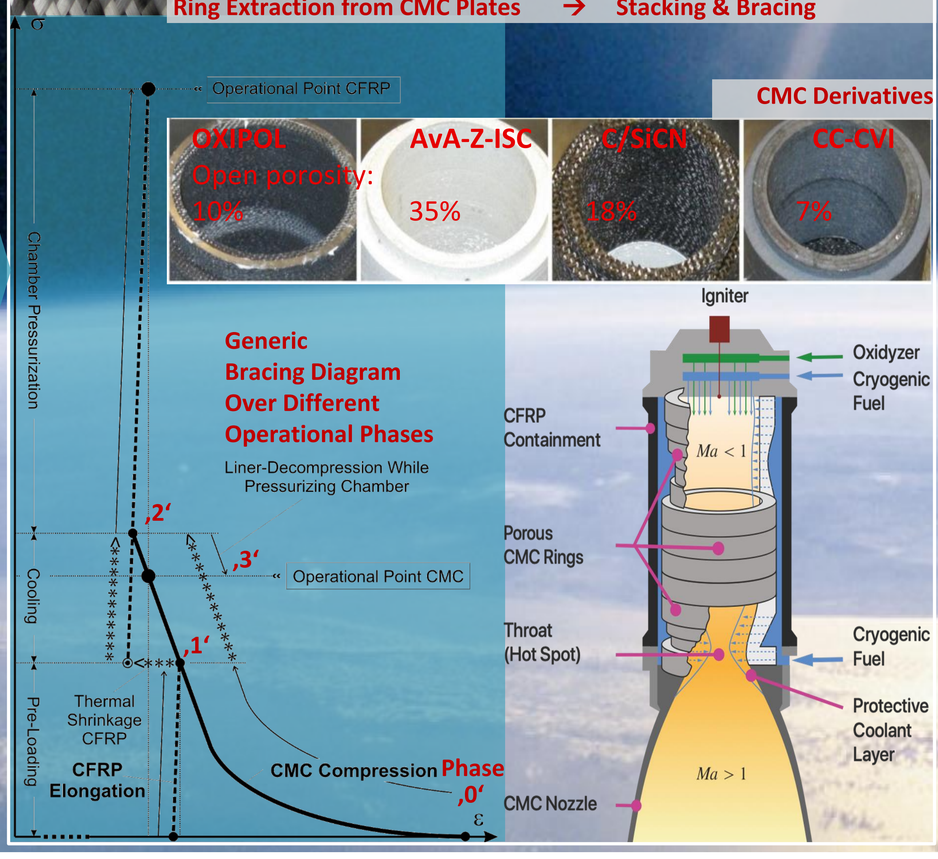
State-
Of-The-Art

Cylindrical
Combustion
Chamber

Structural Setup & Function



Ring Extraction from CMC Plates → Stacking & Bracing

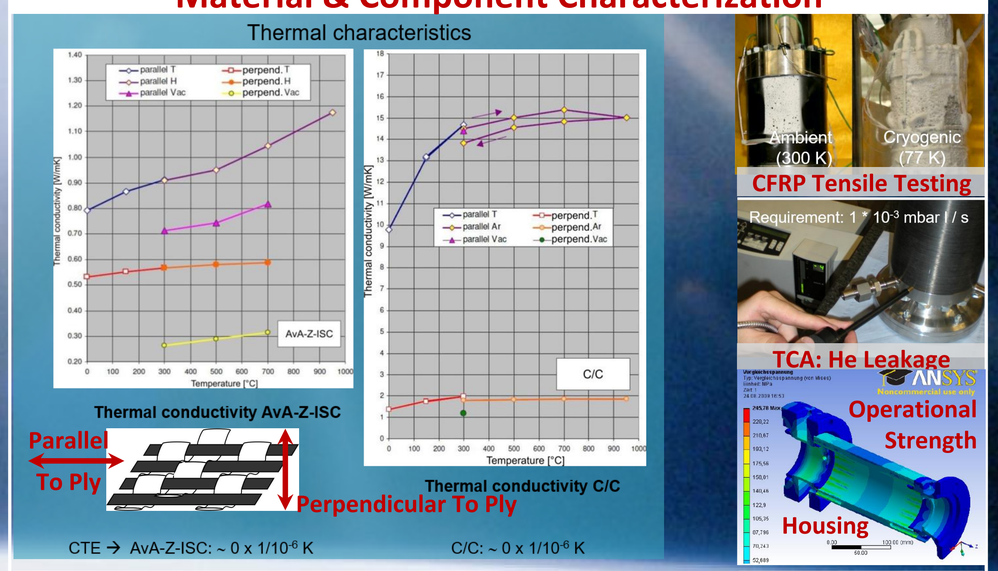


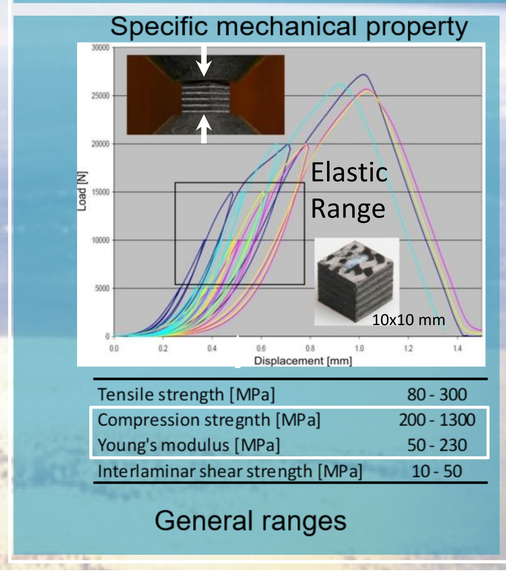
CMC Derivatives

Generic Bracing Diagram Over Different Operational Phases

Liner-Decompression While Pressurizing Chamber

Material & Component Characterization





Tensile strength [MPa]	80 - 300
Compression stregnth [MPa]	200 - 1300
Young's modulus [MPa]	50 - 230
Interlaminar shear strength [MPa]	10 - 50

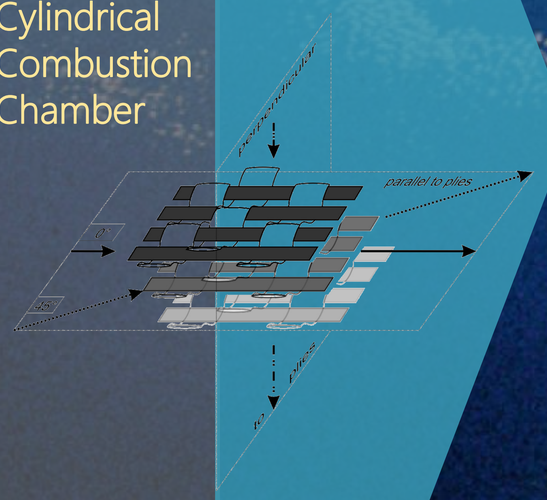
General ranges

Current Demonstrator For 60 kN / LOX/LCH4 Testing

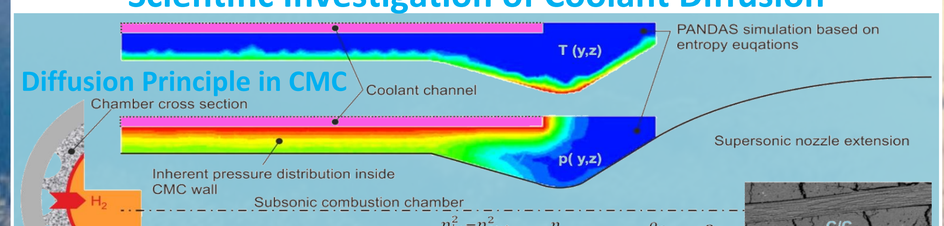
Functional System of the Transpiration Cooled CMC Thrust Chamber Setup & CMC Journal Bearings

State-
Of-The-Art

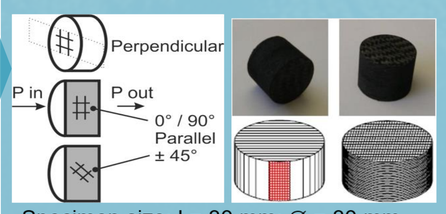
Cylindrical
Combustion
Chamber



Scientific Investigation of Coolant Diffusion



Diffusion measurement



Specimen size: l = 30 mm; ∅ = 30 mm

$$-\frac{dp}{dx} = -\left(\frac{\eta}{k_D}\cdot u + \frac{\rho}{k_F}\cdot u^2\right)$$

	$k_D * e^{-13}$ [m²]	$k_F * e^{-8}$ [m]
C/C (13 % open porosity)	2.2424	2.4355

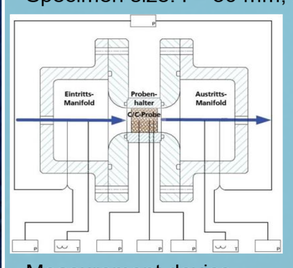
Permeability coefficients of standard C/C

	GN2	GH2
$k_D * e^{-13}$ [m²]	4.8	5.5
$k_F * e^{-8}$ [m]	6.3	6.6

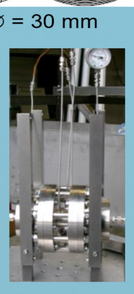
Permeability of different flow media

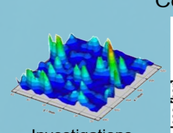
	k_d ∥ /k_d ⊥	k_f ∥ /k_F ⊥
GN2	3.879	2.292
GH2	3.385	2.867

Coefficients of flow anisotropy

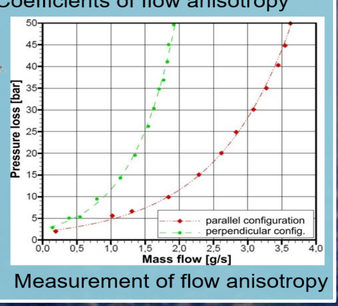


Measurement device





Investigations of effusion homogeneity



Measurement of flow anisotropy

Current Full-Scale Technology Demonstration

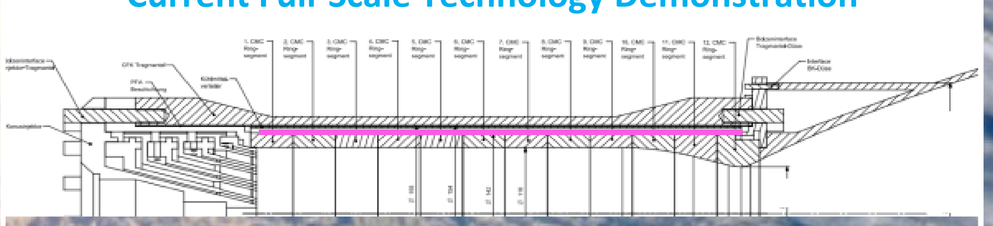


Figure 1: Density distribution of methane in porous liner ($T_c = 225$ K)

Figure 2: Temperature distribution of methane in porous liner ($T_c = 225$ K)

Figure 3: Mainstream domain static temperature distribution of the constant outer diameter porous liner ($T_c = 250$ K, $P_r = 100$ bar)

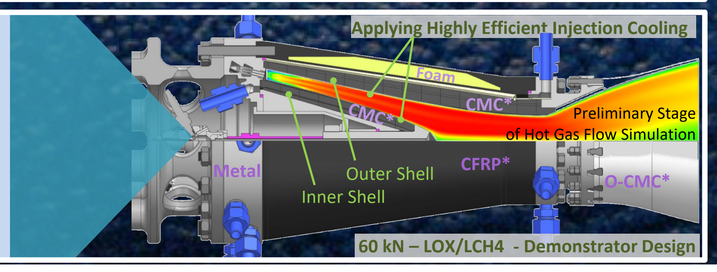
Simulation of the Current Full-Scale 60 kN LOX/LCH4 Demonstrator

Latest
Innovation

Transpiration Lubricated CMC Journal Bearings For Cryogenic Pumps

Dual-Shell Hyperboloid TCA Concept

Maintaining
The Basic
Structural System



Selected References:
1. Greuel, D., Herbertz, A., Haidn, O.J., Ortelt, M., Hald, H., *Transpiration Cooling Applied to C/C Liners of Cryogenic Liquid Rocket Engines,, AIAA 2004-3682*, July 11 - 14 2004, 40th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit.
2. Ortelt, M.; Seiler, H., Boehle, M., Munk, D., *Black Engine Ceramic Rocket Propulsion*, 70th International Astronautical Congress (IAC), Washington D.C., United States, 21-25 October 2019.
3. https://www.compositesworld.com/articles/multi-composite-thrust-chamber-aims-to-boost-rockets-reduce-cost-for-new-space-economy